Absorption and Translocation of Solutions by Healthy and Wilt-diseased Red Oaks

BULLETIN 657

AUGUST 1959

The Pennsylvania State University • College of Agriculture
Agricultural Experiment Station • University Park, Pennsylvania

DIGEST

Absorption and translocation of water, and copper sulphate, azosulfamide (a non-toxic dye), and sodium arsenite (commercial tree killer) solutions by oak wilt-diseased and healthy red oaks was studied to determine volumes absorbed and the rates of movement. Effects of season, soil moisture, soil temperature, and the presence of root grafts and sprouts upon absorption were noted. Solutions were injected into boles of trees by means of a pan-chisel method into recently cut stumps by means of waterproof paper collars, into roots by inverted bottle and siphon methods.

In bole injection studies, movement upward was rapid and extensive in non-diseased trees after bud break, but was restricted to the maximum height of a foot before bud break. The liquids, as indicated by dye patterns observed following felling and sectioning of trunks, moved mostly in the large vessels of the outermost xylem ring. Upward movement in diseased oaks was variable, uneven, and dependent upon the number of tyloses occluding the vessels. Numbers of tyloses were correlated with the percentages of foliar wilt apparent in trees. Downward movement of dye was observed but was limited, especially in diseased trees.

Recently-cut stumps of healthy oaks absorbed significantly greater volumes of solutions than did stumps of diseased trees. Stumps of healthy trees also absorbed significantly different amounts during different seasons; in November, April, and July average absorption per square inch for 100 hours was .3, .2, and .4 liters, respectively. An even distribution of the dye was seen in stumps of healthy trees to the soil line, but an uneven distribution was observed in the stumps of diseased trees, probably due to the development of tyloses. However, an uneven dye pattern was seen in the major roots of the stumps of both diseased and healthy trees. This suggtsts that anatomical connection of xylem elements of trunk and roots may be important in successful and thorough treatment of roots through application of chemicals at the stump. Certainly tyloses prevent thorough treatment of roots of diseased trees by chemical applications to stump surfaces.

Although absorption and translocation of solutions from injected roots of healthy oaks was upward, rapid, and extensive, no downward movement was observed. Members of root grafts were injected at random, and in some instances the dye was not translocated through the union, an indication that not all root grafts are functional.

One interesting root graft discovered in these experiments was found following application of dye to the cut stump of a healthy oak. The dye moved downward through the stump into the roots, through a root graft, and into the trunk of a standing, defoliated, wilt-diseased tree. The dye moved up the trunk in an arc of vessels directly above the root graft. The distance from the center of the stump to the center of the tree was 35 feet and the total length of the two grafted roots was 50 feet.

Absorption and Translocation of Solutions by Healthy and Wilt-diseased Red Oaks*

George Yelenosky and Charles L. Fergus†

OAK WILT is an important disease caused by the fungus *Ceratocystis fagacearum* (Bretz) Hunt. The exact way by which long distance overland spread of this disease is accomplished is unknown, but several means appear possible. Sources of inoculum to originate spread are the mycelial mats produced on the bark and wood (*3*), and spores in the xylem of diseased trees (*10*). Bark peeling or deep-girdling is used to prevent mat formation (*7* and *8*). Insecticide sprays have been recommended to reduce the numbers of insects visiting infected trees (*1*), since insects are believed to spread the spores.

Another method of spread from infected to nearby trees is through root grafts. This is called local spread and is prevented by felling or chemically treating with silvicides all infected as well as the uninfected oaks within a 50-foot radius of the diseased tree (*7*). However, stump sprouts and living roots found on treated trees several years following treatment indicate that the treatment does not eliminate diseased trees or stumps as possible inoculum sources or the surrounding healthy trees as transmission routes. The fungus may pass from an infected tree through root grafts into newly formed sprouts of adjacent stumps of healthy trees, and then through more root grafts into healthy trees beyond the perimeter of the eradication zone.

No means of saving an oak wilt diseased tree is known; hence, the ideal chemical to destroy the infection would be toxic to the living tree, toxic to the fungus, and easily translocated throughout the root system. Through careful study, methods of application may be developed to materially aid absorption and translocation of the chemicals presently used. The influence of environment, physical state of the tree, season, and the place of introduction of the chemical into the tree for absorption and translocation have been investigated in hopes of discovering the best method of treatment.

MATERIALS AND METHODS

All of the trees used in these experiments were red oaks, *Quercus rubra* L., ranging from 4 to 12 inches in diameter at breast height. Healthy and diseased (artificially inoculated with conidia of *Ceratocystis fagacearum* ((Bretz) Hunt) trees were injected with dyes and

* Authorized for publication June 22, 1959.
Contribution No. 238 from the Department of Botany and Plant Pathology.

† Research Assistant and Associate Professor of Botany and Plant Pathology, respectively.

ACKNOWLEDGEMENTS: The advice, help, and cooperation of W. J. Stambaugh, Assistant Professor of Forest Pathology, of J. C. Nelson of the Pennsylvania Department of Forests and Waters, and of F. C. Craighead and R. C. Sanderson of the Pennsylvania Department of Agriculture is gratefully acknowledged.

This study is part of Regional Project NE-25, "Biology and Control of Wilt Pathogens," a cooperative study involving agricultural experiment stations in the Northeast Region and supported in part by regional funds of the United States Department of Agriculture.

FIG. 1. — Aluminum frustrum in place for use in introduction of solutions into standing trees in the pan and chisel method.

various other chemical solutions. Chemical injections into diseased trees were made during various stages of wilting. The experiments were performed in January, April, May, June, July, and August, 1957, near Blain, Perry county.

Four different methods were used to introduce the solutions into the vascular systems. They were: the pan and chisel method, fig. 1, as described by Greenidge (5), for trunk injections of standing trees; the collar method, developed at the Blain Laboratory (2) and described by True, *et al.* (9), for topped tree injections and stump absorption, figs. 2 and 3; a siphon method for root injections, fig. 4; and an inverted bottle method for branch and root injections, fig. 5.

The pan and chisel method was performed as follows: aluminum frustrums filled with solution were attached to the trees at various trunk heights not exceeding 5 feet above the ground. In placing a frustrum, the outer bark was first smoothed with a hand axe, caution being taken not to penetrate into the inner bark. The smoothed area of frustrum contact was covered with a narrow band of roofing cement. The frustrum was then placed around the trunk of the tree with the lower end directly on top of the asphalt band. The overlapping frustrum ends were cemented together with roofing compound and held in place with a small clamp. A strip of rubber tubing was then tightly wrapped around the lower edge of the frustrum and taped in place with permacel tape. The cemented overlapping edges were also taped and the clamp removed thus providing a water tight seal. At this point, the frustrum was filled with solution. The tree circumference was incised carefully into the sapwood, but never deeper than one-half inch. The incisions were always made under the solution with a chisel, fig. 1. Three trees were injected in each treatment.

In a somewhat similar manner, topped trees were injected by attaching paper collars to trunks after they were sawed through at the point of the foliar crown. Chemicals also were placed in collars attached to stumps 1 foot above the ground line after the trunks had been cut through with a bow saw. Each trunk exterior just below

FIG. 2. — The collar method used to introduce solutions into topped trees and stumps.

FIG. 3. — Protective cone-like covering in place over a treated stump.

the saw cut was covered with asphalt roofing cement. A strip of water-proof paper was then properly placed, the overlapping edges being cemented together with roofing cement. A strip of rubber tubing was then tightly wrapped around the lower edge of the collar. Permacel tape was used to hold the rubber strip in place and also as a reinforcement for the overlapping collar edges. A solution was immediately poured into the collar when the attachment was completed. All of the treated stumps were protected by cone-shaped, waterproof paper covers, fig. 3. A total of 30 stumps were studied.

Root injections were made by use of the siphon method illustrated in figure 4. A large glass container was filled with the selected solution and fitted with a 2-hole rubber stopper. Two glass tubes were then inserted into the stopper. One tube, vented to the atmosphere, was bent at a right angle. A rubber hose fitted with a clamp to control solution flow was attached to the other glass tube. The root selected for study was incised with a sharp knife and the rubber tubing fitted over it. The hose clamp was immediately loosened and solution flow started.

In the inverted bottle method, fig. 5, an ordinary milk bottle was utilized. The bottom was removed and a 2-hole rubber stopper was fitted into the mouth. Two short sections of glass tubing were inserted into the stopper and rubber hoses were attached to each of the

FIG. 4. — Injection of a root by the siphon method.

FIG. 5. — Injection of a root by means of an inverted bottle method.

glass tubes. By this method two roots could be injected at the same time. When injecting roots, the apparatus, inverted to turn the mouth of the bottle down, was supported above the specific roots by a metal tripod ring stand. The solution was then added to the bottle. When free solution flow was observed through the rubber hoses, their ends were clamped. A sharp knife was then used to sever two roots at desired points of attachment, the rubber hoses were attached to the severed root ends and the clamps were removed. In branch injections, the inverted bottle was taped to a branch within the tree's crown; usually only one hose was attached, the other being closed.

Absorption of solutions were determined through use of calibrated containers for definite lengths of time. Dye translocation patterns in trunks and branches were determined by felling, peeling, and sectioning treated trees. Roots were excavated manually and sectioned to determine dye movement. Copper sulphate (45 grams per liter), azosulfamide (5 grams per liter), sodium arsenite (1 pint "Penite 6" per gallon of water), and water alone, were the materials studied. Azosulfamide (9) was the only chemical used in the trunk, topped tree, and root injections. All four chemicals were applied singly in the stump absorption study. The presence and path of movement of azosulfamide was determined by visual observation of a red stain. In like manner, copper suphate invoked a blackish coloration and was further identfied by the development of a copperish tone following application of 1 per cent $K_4Fe(CN)_6$ to stained areas.

The possible phytotoxicity of azosulfamide was determined in a preliminary experiment by submersing the ends of cut oak branches and excavated oak seedlings in azosulfamide solution in glass containers. In addition, the soil in which seedlings were growing was saturated with azosulfamide at various time intervals. A slight marginal necrosis of the leaves after two months was the only visible deleterious effect.

Soil samples were obtained at each of the treatment sites with an auger having a sleeve attachment. They were taken at depths of 8 to 14 inches at each of the 4 major compass points directly beneath the crown of peripheries of standing trees and around treated stumps. The samples, 1 inch in diameter and 2 inches long, were immediately placed in waterproof half-pint mason jars. The maximum holding time within the jars did not exceed 48 hours. The samples were oven-dried at 110 degrees Centigrade for 12 hours, soil moisture percentages being based on the oven-dry weights in grams. In addition, soil temperatures were determined at the various sampling holes with a Weston dial thermometer. Air temperatures also were recorded for the same period.

Since evaporation may influence apparent absorption, determinations were made of losses from samples of water and of copper sulphate and azosulfamide solutions from stumps for 10 consecutive days in July. To prevent infusion into the wood, the entire transverse area of the stump used in each test was covered with asphalt roofing cement prior to pouring the solution into the collar.

RESULTS

Trunk Injections — Healthy Trees

Following introduction of azosulfamide into trees by the pan and chisel method, the dye was observed as a continuous red-colored ring in the sapwood of healthy trees. The vessels of the sapwood were the only vascular elements stained. Longitudinally, with increasing distance from the point of injection, the dye became more localized to the extreme outer vessels.

When injected in January, the dye did not rise more than 9 feet in any tree. Some vessels were stained at greater heights than others, consequently the longitudinal exterior surface of the sapwood was stained unevenly. On the transverse view, the sapwood was dyed unevenly. The degree of uneven staining increased with increasing height. In the April injections, the dye did not rise more than 5 feet and the uneven dye distribution was again observed. However, in May the dye moved 47 feet upward into the crown of a 50-foot oak. Six hours after injection the dye was visible in all the leaves of the entire foliar crown. The leaves were first a light red, then darker. The dye was evenly distributed throughout the sapwood of the trunk of the tree. Similar results were obtained in June; however, only 2 hours were required for complete dye distribution.

Downward translocation below the injection point was observed in all treatments. In the transverse view, the dye pattern was a continuous ring in the sapwood. Only the vessels were stained. The continuous dye ring was observed to the vicinity of the root collar, but in the major roots an uneven pattern was noted. As the distance from the root collar increased and the larger roots branched, the number of vessels showing the dye decreased. A variable dye distribution was noted in the large roots, but the vessels nearest the soil surface were consistently dyed. In January and April, the dye did not move more than 2 feet from the root collar. Eight feet was the maximum movement observed in May, June and July.

In April at the time of treatment, soil and air temperatures were 39 and 46 degrees Fahrenheit, and in May, 50 and 68 degrees, respectively. Buds began to develop in mid-April and mature leaves had formed by May 7.

Beginning on April 24, 11.5 liters of water were absorbed during a period of 451 hours by a 5-inch diameter red oak. Powdered azosulfamide was then added to the water in the frustrum. One month later the tree was felled and examined. The dye had moved only 3 feet above the injection point. Downward movment occurred with a uniform distribution of dye to the vicinity of the root collar, beyond which the pattern became uneven.

In July, a healthy red oak was subjected to the double cut treatment of Greenidge (6), wherein the bark was removed all around the trunk 2 feet above and 2 feet below the injection point immediately prior to injection, and saw cuts were made halfway through the tree circumference. Immediately after injection, the dye was visually observed by means of a 14x hand lens moving downward in a few of the vessels. Individual vessels showed different rates of dye movement; a rate of 3 feet per minute was seen in one. Approximately 3 minutes after the initial downward movement, the dye was observed moving upward at less than 1 foot per minute. As the dye reached the lower bole cut, the movement stopped in the excised vessels but continued in the vessels that had not been severed. The dye moved up to the second bole cut and stopped. Ten minutes later a circumferential movement of approximately one-half inch was observed between the two cuts. This movement continued until the top cut was longitudinally by-passed. Then the movement was predominately upward. Figure 6 illustrates the dye pattern observed the following day.

The influence of a prior absorption of 2 liters of saturated aqueous solution of picric acid was determined. The only observable difference was a localization of dye absorption in the extreme outer portion of sapwood below the injection point, fig. 7. Absorption without prior treatment with picric acid resulted in a staining of all of the sapwood.

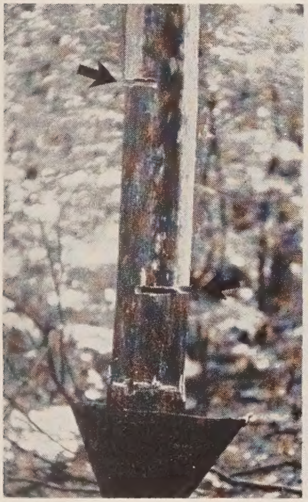

FIG. 6. — Distribution of azosulfamide in a healthy red oak subjected to the double cut treatment. The darkened trunk area indicates the presence of the dye. Arrows point to the bole cuts.

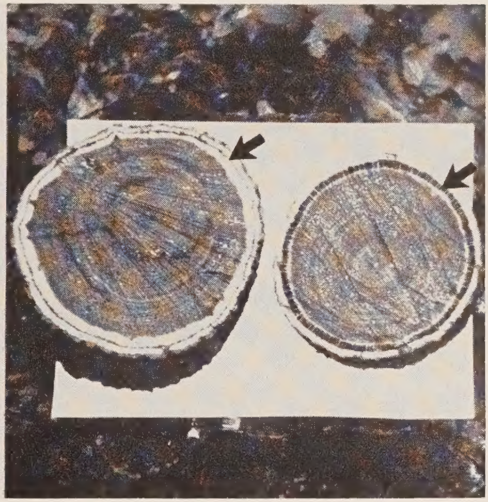

FIG. 7. — Distribution of azosulfamide in trunks of healthy red oaks following picric acid treatment. The left section is from below the injection point and the right section is from the trunk above it. The arrows point to the sapwood which became stained by the dye. Note the different widths of the stained sapwood.

Root Injections — Healthy Trees

In July, two adjacent, healthy red oaks were injected through the roots by the siphon method. One root of one tree was injected with water while a root of an adjacent tree was injected with azosulfamide. The crown classification, diameter at breast height, total height, crown width, and crown ratio for each of the trees subjected to water and aszosulfamide were respectively: codominant, dominant; 9.0 inches, 11.0 inches; 58 feet, 75 feet; 17 feet, 28 feet; and 38 per cent and 34 per cent. The diameter of each root at the point of injection was ⅜ inch, and the root length from point of injection to the bole was 12 feet. Maximum rates of absorption occurred within the first 24 hours. Water was absorbed approximately twice as fast as the azosulfamide solution. A marked decrease in absorption occurred after 30 hours. Following the fourth day, neither tree absorbed any more solution. Exchanging the solutions between the two trees and making a new point of injection on each root, did not result in any measurable absorption. After 9 days, the total volumes absorbed were 4 liters of water and 1½ liters of azosulfamide solution.

Roots of three healthy red oaks were also injected with azosulfamide by the inverted bottle method. In all injections a positive absorp-

tion was observed. Usually only the foliage of the injected tree directly above the injected root became stained. The vessels of the trunk directly above the injected root became stained, but not those all around the trunk. Excavation and sawing revealed that the sapwood of the injected roots was stained evenly throughout its circumference, but an uneven pattern was found in the root collar — trunk zone at soil level.

Topped Tree and Branch Injections — Healthy Trees

By use of the collar method, positive absorption of azosulfamide was obtained through cut trunks of trees. The dye was found throughout trunks and also in major roots which were excavated in this instance for a distance of only 1 foot from the root collar. An even distribution was observed in the sapwood of trunks and an uneven pattern in the sapwood of roots.

Injecting crown branches with azosulfamide resulted in both upward and downward movement; however, the dye was localized to sapwood longitudinally oriented with injected branches.

Trunk Injections — Diseased Trees

Eight oak wilt-diseased trees, each approximately 55 feet high, were injected with azosulfamide by the pan and chisel method in June and July 1957. The absorption rate was extremely slow in contrast to that of healthy oaks. The dye moved into the foliage of only three of the eight trees. The maximum height observed was 52 feet in the tree which showed the least wilt symptoms; approximately 25 per cent of its foliage had turned brown. The dye was seen only in the lower leaves of the other 2 trees which showed 40 per cent browned foliage. The dye moved into wilting leaves but never into leaves that had already browned. The closest that the dye moved to the browned leaves was 1 foot from the petioles. In the remaining 5 trees, the maximum height of dye movement was 24 feet. Approximately 75 to 100 per cent of their leaves were browned when these trees were injected.

Dye distribution in the trunk sapwood was very uneven, and as distance increased from the point of injection, distribution became more uneven, fig. 8. In six of the trees a band of sapwood approximately ⅜ inch wide extending the length of the trunk showed no dye. This strip was directly oriented longitudinally with the fungus inoculation point. The dye moved downward in all the injected trees, and in the root collar area the dye pattern was very irregular. Tyloses were observed in variable numbers in the trunks.

Root Injections — Diseased Trees

Azosulfamide was absorbed very slowly by roots of diseased oaks. One tree which had no green leaves had a total absorption of 300 milliliters for 20 days, or less than 1 ml. per hour. The maximum height of dye movement in trees averaging 50 feet in height, was

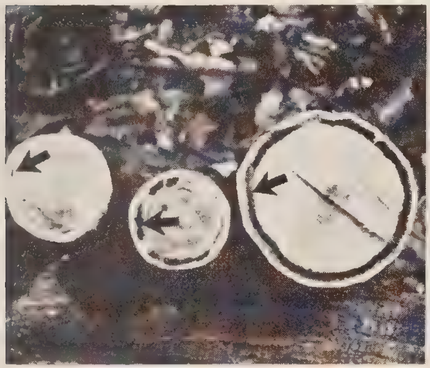

FIG. 8. — Distribution of azosulfamide in trunk sections of an oak wilt-diseased tree. The arrows point to the stained sapwood. Distribution became more irregular as the distance from the point of injection increased. The left section was from the greatest height.

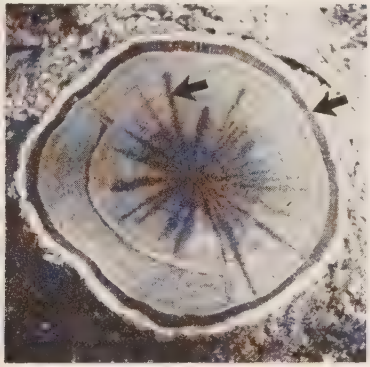

FIG. 9. — Radial cracks in a healthy red oak tree stump which became stained with the azosulfamide. The right arrow points to the sapwood which became stained by the dye, and the left arrow points to a radial crack.

8 feet. An uneven dye pattern was observed in injected roots and also in the respective trunks. No tyloses were seen in transverse sections of roots. A variable dye distribution was observed in injected roots that were grafted to other roots. In some instances, the dye failed to move through such grafts.

Topped Tree Injections — Diseased Trees

The collar method was used to introduce the dye into the tops of several trunks of diseased trees. Absorption was very slow and downward movement in any trunk did not exceed half its total length. The dye was distributed very unevenly in the sapwood. Tyloses were observed in large numbers in transverse sections of the trunks.

Stump Absorption Investigations

A total of 30 oak stumps were treated in three separate studies: eight healthy and four oak wilt-diseased trees were treated in November, 1956; six healthy and three diseased trees were treated in April; and a like number were treated in July, 1957. In November, copper sulphate at 45 grams per liter, azosulfamide at 35 grams per liter, sodium arensite at 1 pint "Penite 6" per gallon of water, and water alone were the solutions studied. In April and July, sodium arsenite was excluded and the concentration of azosulfamide was only 5 grams per liter of water.

The data for five of the treated stumps could not be used due to solution seepage through radial cracks and root injuries of unknown origin, fig. 9. This factor, plus the extreme variability of the absorption data obtained with the remaining stumps, prevents expressing the

data for each solution by itself. Consequently, the volumes of solution absorbed were combined and expressed as volumes per square inch of sapwood, table 1.

TABLE 1. — Average milliliters per square inch of sapwood of copper sulphate, sodium arsenite and azosulfamide solutions, and water absorbed during 100 hours by stumps of healthy and diseased oak trees, combined data, 1956-57.

DATE OF TREATMENT	STUMPS OF HEALTHY TREES		STUMPS OF DISEASED TREES	
	Number	Average per Stump	Number	Average per Stump
		ml/sq in		*ml/sq in*
Nov. 1956	6	302	3	192
April 1957	5	211	3	130
July 1957	5	404	3	152

The stumps of the healthy trees absorbed the largest volumes in July and the least in April, while those of diseased trees absorbed the most in November and the least in April. In all treatments, the stumps of healthy trees absorbed greater volumes than those of diseased trees.

Figures 10, 11, 12, and 13 illustrate absorption as related to time. A seasonal difference is apparent. No significant influence of soil moisture on absorption was discerned, fig. 13.

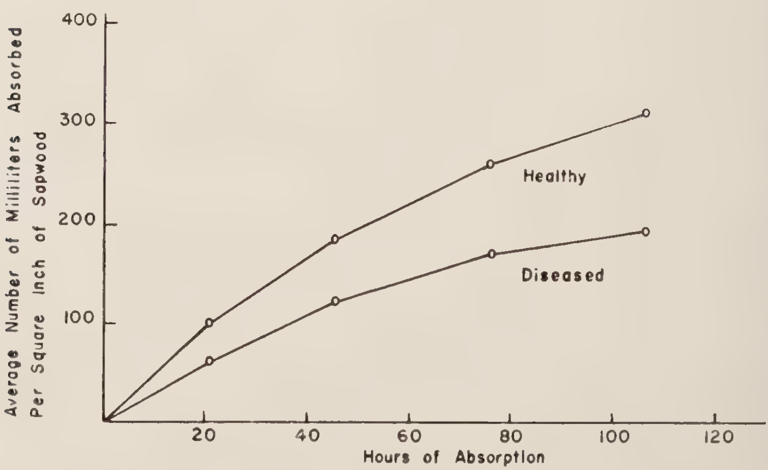

FIG. 10. — Average milliliters of combined solutions (copper sulphate, water, azosulfamide, and sodium arsenite) absorbed by stumps of six healthy and three diseased trees during November 1956, per square inch of sapwood.

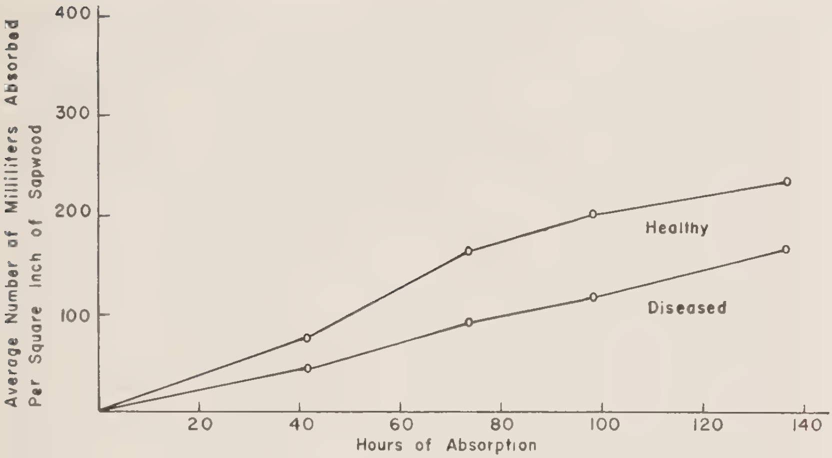

Fig. 11. — As in figure 10 for April 1957.

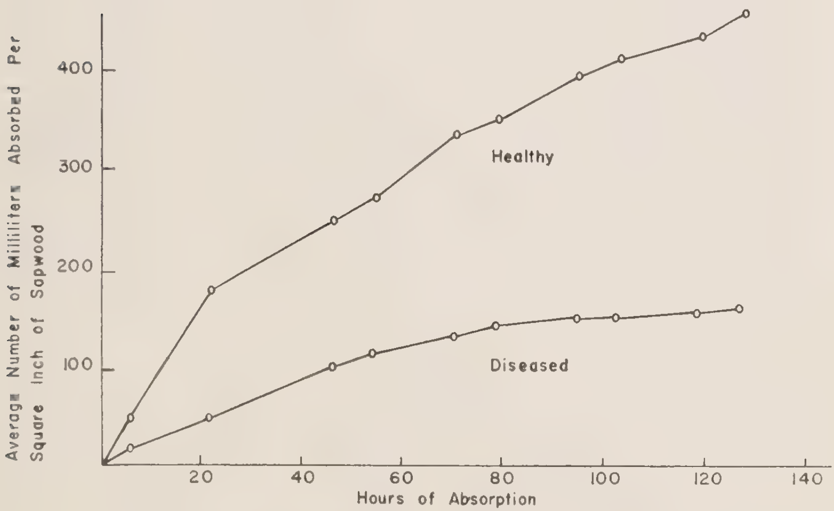

Fig. 12. — As in figure 10 for July 1957.

Tyloses were not seen in the sapwood vessels of the stumps of healthy trees; however, they were abundant in the vessels of stumps of diseased trees, approximately 50 per cent of the vessels being closed.

Azosulfamide showed as a continuous dye ring in the sapwood of stumps of healthy trees, but only the vessels appeared to be dyed. An uneven distribution of dye was noted in the major roots, and this unevenness increased with distance down the root and away from the treated stump. The dye was found in all the roots attached to

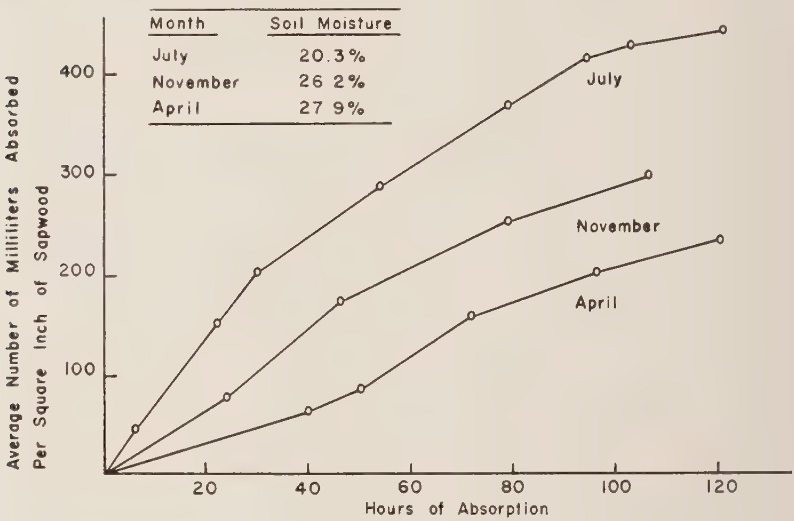

FIG. 13. — Average milliliters of combined solutions (copper sulphate, water, azosulfamide, and sodium arsenite) absorbed by stumps of healthy trees during the different periods of treatment.

the stumps, even in rootlets as small as one-eight of an inch in diameter. The maximum distance of dye movement in a root was 18 feet. Examination of transverse sections of the roots revealed that the dye was generally in the outer vessels. Occasionally, the innermost vessels were dyed, but the outer vessels were not. As root diameter decreased the entire transverse xylem showed the dye.

In contrast to the stumps of healthy trees, an uneven distribution of the dye immediately below the treated stumps of diseased trees appeared, fig. 14. In all instances, abundant tyloses were observed in the unstained sapwood vessels. No tyloses were found in the vessels that showed dye movement. The dye was not found in all the major roots of the treated stumps. Tyloses were infrequent in the vessels of the roots.

Testing for copper sulphate with potassium ferrocyanide was satisfactory for a week following chemical treatment. Beyond this period the copperish reaction color was difficult to detect.

Root Grafts

Root grafts were infrequently found in this investigation; however, one was so unique that it will be described. Azosulfamide was applied to a stump of a healthy tree in November 1956. In May 1957 it was discovered that the dye had moved through a root graft into an adjacent diseased tree which was completely defoliated. The distance from the center of the stump to the center of the tree was 34.6 feet. The total actual root length of the 2 grafted roots, after excava-

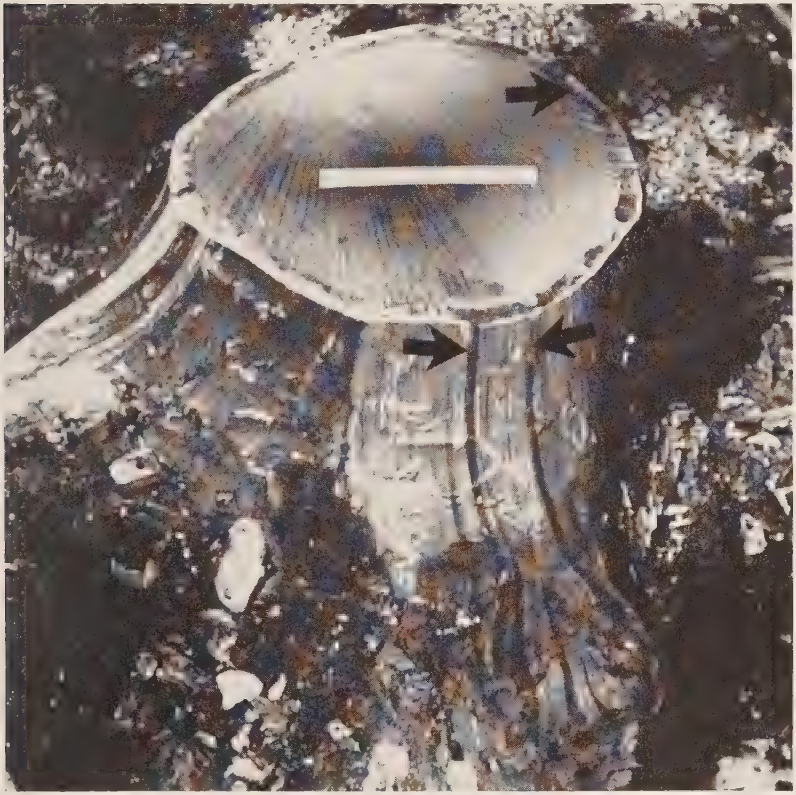

Fig. 14. — Absorption of azosulfamide by the stump of an oak wilt-diseased tree. Note the uneven dye pattern. The arrows point to stained sapwood.

tion, proved to be 50 feet. The sapwood area of the trunk of the diseased tree that showed the dye was a small vertical column vertically oriented above the grafted root. The dye had moved 14 feet up the trunk of the diseased tree.

Loss by Evaporation

Solution losses by evaporation from treated stumps fitted with collars averaged less than 50 ml. in 10 days. The maximum recorded temperature was 92 and the minimum was 43 degrees Fahrenheit. The average maximum temperature was 82 and the average minimum was 52 degrees F.

DISCUSSION

Injection of solutions into healthy red oak trees was readily attained by direct application to incised vessels, regardless of the

method used or place of introduction. The general distribution of the dye in healthy red oaks is similar to that found by Greenidge (*6*) in other ring-porous species such as ash and elm. Greenidge (*4*) also reported that ring-porous species have continuous water conducting elements extending from the crown to the ground level. In addition, he suggested that these elements extend into the roots. In the experiments reported herein, observation of an even distribution of dye in the sapwood and restriction of the dye to the xylem vertically oriented with the injection points support his findings. However, uneven dye distribution in the roots suggests an interruption or discontinuity of vascular elements of trunk and root.

Temperature may influence the uptake and movement of chemical solutions, and this may be the explanation for the differences observed during the different treatments. Temperatures of −8 degrees F in January, 9 in March, and 21 in April were recorded in the research area. Consequently, different heights of dye movement would be expected. In addition, foliage was not present on the trees during these months and therefore transpiration was greatly reduced. A more rapid and greater uptake of chemical solutions would be expected under conditions of greater transpiration.

Different moisture contents of trees also effect the uptake and movement of solutions in artificially injected trees. This effect was observed in the red oak which was first injected with water for approximately 450 hours and then injected with azosulfamide. The dye did not rise more than 3 feet.

No rapid or drastic toxic effect of the dye was noted in the phytotoxicity study. It is assumed that the distribution patterns of the dye observed in the experiments were not influenced by a toxic effect on the living cells in the wood or in the leaves. Picric acid is toxic to living cells, but its introduction into trees prior to dye injection did not result in any marked difference in dye distribution.

In the diseased trees, some form of vascular disruption was very apparent. In contrast to the healthy trees, solutions were absorbed in smaller volumes, at slower rates, with less vertical movement, and very irregularly. The presence of tyloses in the sapwood vessels of diseased trees explains such a disruption.

Correlation, fig. 13, between soil moisture and stump absorption was not obtained; however, interpretation of the data is difficult since the soil moisture did not vary greatly. One would expect rainfall to influence uptake of liquids by stumps. Nelson and Craighead* reported that in very rainy seasons cut stumps actually exuded large quantities of liquid, causing an overflow of the collars.

The gradual reduction of absorption by stumps as the time of absorption lengthened, as found in these studies, agrees with the

* Personal communication to the authors.

results of True, *et al.* (9). The stumps and root systems absorbed less and less as their saturation deficit decreased.

The grafting distance of 50 feet of actual root length, found in the stump absorption study, is of considerable significance in the local control technique. Usually trees are eradicated to a maximum radius of 50 feet. Control agencies should not ignore the possibility of the need to increase the radius.

Movement of dye into a defoliated diseased tree from the stump of the healthy tree through root grafts indicates that transpirational loss from trunk and branch surfaces must occur. In addition, capillarity and atmospheric pressure may help explain this dye movement. Although the dye passed through this particular graft, other grafts were discovered through which the dye failed to move. Thus the mere presence of a morphological union is not conclusive proof that a functional vascular connection exists between roots of grafted trees.

In using chemicals to kill the healthy trees surrounding a wilt-killed tree, possibility of an adequate treatment of the root system does not appear to be very great. Irregular distribution of the dye in the roots prevents their complete killing; hence, later sprouting could be expected. This is borne out indirectly by the fact that such sprouting has occurred in control areas in the State. A possible vascular discontinuity in the trunk-root collar-root zone may be responsible for such uneven distribution of applied chemical solutions. However, distribution of the dye may not be representative of all chemical solutions. It is possible that chemical treatment of the root collar at the soil level, or slightly below, would result in a more thorough distribution of the applied chemicals. Treatment of diseased trees above the soil line does not promise an adequate movement downward due to the vessel occlusions.

BIBLIOGRAPHY

(1) Boyce, J. S., Jr. 1954. Spraying logs of oak wilt trees to reduce infection hazard. *Southeastern For. Exp. Sta. Res. Note* 52. 2 pp.

(2) Craighead, F. C., and W. J. Stambaugh. 1955. Progress report on the Pennsylvania oak wilt investigations at the Blain Laboratory for 1955. *Mimeo.* 14 pp.

(3) Fergus, C. L. 1953. Mycelial mats of the oak wilt fungus. *Pa. Agri. Expt. Sta. Progress Report* 100. 8 pp.

(4) Greenidge, K. N. H. 1952. An approach to the study of vessel length in hardwood species. *Amer. Jour. Bot.* 39: 570-574.

(5) Greenidge, K. N. H. 1953. Further studies of birch dieback in Nova Scotia. *Can. Jour. Bot.* 31: 548-559.

(6) Greenidge, K. N. H. 1955. Studies in physiology of forest trees. III. The effect of drastic interruption of conducting tissues on moisture movement. *Amer. Jour. Bot.* 42: 582-587.

(7) Kuntz, J. E., and A. J. Riker. 1956. Oak wilt. *Wisc. Agri. Expt. Sta. Bul.* 519. 12 pp.

(8) Stambaugh, W. J. 1957. Mycelial mats of the oak wilt fungus and their relation to overland disease spread. *Unpublished Ph.D. Thesis. Yale Univ.*

(9) True, R. P., T. M. Judy, and E. Ross. 1955. The absorption of solutions through the tops of freshly cut oak stumps. *W. Va. Agr. Expt. Sta. Current Rpt.* No. 11.

(10) Young, R. A. 1949. Studies on oak wilt, caused by *Chalara quercina. Phytopath.* 39: 425-441.